particular object or scene would affect the individuals viewing it. The nearly 1,800 persons who pass by L-Lake each day are SRS workers accustomed to changes in the Site landscape who might not consider these changes significant, assuming they perceive SRS as strictly an industrial complex.

4.1.7.2.3 Shut Down and Maintain

The consequences of this alternative would be the same as those for the Shut Down and Deactivate Alternative, except DOE could restart the River Water System if necessary. Section 3.3.1 contains possible reasons for restarting the system.

4.1.8 OCCUPATIONAL AND PUBLIC HEALTH

4.1.8.1 Affected Environment

4.1.8.1.1 Public Health

A release of radioactivity to the environment from a nuclear facility is an important issue for both SRS workers and the public. However, the environment contains many sources of ionizing radiation, and it is important to understand all such sources to which people are routinely exposed.

Sources of Environmental Radiation

Environmental radiation consists of natural background radiation from cosmic, terrestrial, and internal body sources; radiation from medical diagnostic and therapeutic practices; radiation from weapons test fallout; radiation from consumer and industrial products; and radiation from nuclear facilities. All radiation doses mentioned in this EIS are effective dose equivalents (i.e., organ doses are weighted for biological effect to yield equivalent whole-body doses) unless specifically identified otherwise (e.g., absorbed dose, thyroid dose, bone dose).

Releases of radioactivity to the environment from the SRS account for less than 0.1 percent of the total annual average environmental radiation dose to individuals within 50 miles (80 kilometers) of SRS (Arnett, Mamatey, and Spitzer 1996).

Natural background radiation contributes about 82 percent of the annual average dose of 360 millirem received by an average member of the population within 50 miles (80 kilometers) of SRS (Figure 4-21). Based on national averages, medical exposure accounts for an additional 15 percent of the annual dose, and the combined doses from weapons test fallout, consumer and industrial products, and air travel account for about 3 percent of the total dose (DOE 1995c).

External radiation from natural sources comes from cosmic rays and emissions from natural radioactive materials in the ground. The radiation dose to the individual from external radiation varies with the exposure location and altitude.

Internal radiation from natural terrestrial sources consists primarily of potassium-40, carbon-14, rubidium-87, and daughter products of radium-226 that people consume in food grown with fertilizers containing these radionuclides. The estimated average internal radiation exposure in the U.S. from natural radioactivity (primarily indoor radon daughter products) is 240 millirem per year.

Medical radiation is the largest source of man-made radiation to which the population of the U.S. is exposed. The average dose to an individual from medical and dental X-rays, prorated over the entire population, is 39 millirem per year (DOE 1995c). In addition, radiopharmaceuticals administered to patients for diagnostic and therapeutic purposes account for an average annual dose of 14 millirem prorated over the population. Thus, the average medical radiation dose in the U.S. population is about 53 millirem per year. Prorating the dose over the population determines an average dose that, when multiplied by the population size, produces an estimate of population exposure; it does not mean that every member of the population receives a radiation exposure from these sources.

In 1980 the estimated average annual dose from fallout from nuclear weapons tests was 4.6 millirem (0.9 millirem from external gamma radiation and 3.7 millirem from ingested radioactivity). Because atmospheric nuclear weapons tests have not occurred since 1980, the average annual dose from fallout is now less than 1 millirem. This decline is due principally to radioactive decay.

A variety of consumer and industrial products yield ionizing radiation or contain radioactive materials and, therefore, result in radiation exposure to the general population. These sources include televisions, luminous dial watches, airport X-ray inspection systems, smoke detectors, tobacco products, fossil fuels, and building materials. The estimated average annual dose for the U.S. population from these sources is 10 millirem per year (DOE 1995c). About one-third of this dose is from external exposure to naturally occurring radionuclides in building materials.

People who travel by aircraft receive additional exposure from cosmic radiation because at high altitudes the atmosphere provides less shielding from this source of radiation. The average annual airline passenger dose, prorated over the entire U.S. population, amounts to 1 millirem (DOE 1995c).

Radiation Levels in the Vicinity of SRS

Figure 4-21 summarizes the major sources of exposure for the population within 50 miles (80 kilometers) of SRS and for populations in Beaufort and Jasper Counties, South Carolina, and Chatham County, Georgia, that drink water from the Savannah River. Many factors, such as natural background dose and medical dose, are independent of SRS.

Atmospheric testing of nuclear weapons deposited approximately 25,600,000 curies of cesium-137 on the earth's surface (DOE 1995c). About 104 millicuries of cesium-137 per square kilometer were deposited in the latitude band that includes South Carolina (30°N to 40°N). The total resulting deposition was 2,850 curies on the 10,580 square miles (27,400 square kilometers) of the Savannah River watershed and 80 curies on SRS. The cesium-137 attached to soil particles and has slowly moved from the watershed. Results from routine health protection monitoring programs indicate that since 1963 about 1 percent of the 2,850 curies of cesium-137 deposited on the total Savannah River watershed has been transported down the river (DOE 1995c).

Onsite monitoring shows an average of 50 millicuries of cesium-137 per square kilometer (1976 to 1982 average) in the upper 2 inches (5 centimeters) of the soil column; this is half the original amount. Some of the cesium has moved down in the soil column, and some has moved in surface water to the Savannah River.

Other nuclear facilities within 50 miles (80 kilometers) of the SRS include a low-level waste burial facility operated by Chem-Nuclear Systems, Inc., near the eastern Site boundary, and Georgia Power Company's Vogtle Electric Generating Plant, located directly across the Savannah River from the Site. In addition, Carolina Metals, Inc., which is northwest of Boiling Springs in Barnwell County, South Carolina, processes depleted uranium. The Chem-Nuclear facility, which began operating in 1971, releases essentially no radioactivity to the environment (DOE 1995c), and the population dose from normal operations is very small. The 50-mile- (80-kilometer-) radius population receives an immeasurably small radiation dose from the transportation of low-level radioactive waste to the burial site. Plant Vogtle began commercial operation in 1987, and its releases to date have been far below DOE guidance levels and Nuclear Regulatory Commission regulatory requirements (DOE 1995c).

In 1995 releases of radioactive material to the environment from SRS operations resulted in a Site boundary maximum dose from all pathways from atmospheric releases of 0.06 millirem per year (in the west-southwest sector), and a maximum dose from releases into water of 0.14 millirem per year, for a maximum total annual dose at the SRS boundary of 0.20 millirem. The maximum dose to downstream consumers of Savannah River water, to users of the Beaufort-Jasper public water supply, was 0.05 millirem per year (Arnett, Mamatey, and Spitzer 1996).

In 1996 the population within 50 miles (80 kilometers) of SRS was 672,122 (Simpkins 1996b). The collective effective dose equivalent to this population in 1995 was 3.5 person-rem from atmospheric releases. Table 4-11 lists the population distribution for the 50-mile (80-kilometer) population. The 1990 population of 65,000 people using water from Port Wentworth (Savannah), Georgia, and from Beaufort and Jasper Counties, South Carolina received a collective dose equivalent of 1.6 person-rem (Arnett, Mamatey, and Spitzer 1996).

DOE conducts controlled deer and hog hunts annually at SRS to control their populations. Field measurements performed on each animal before its release to the hunter determine the levels of cesium-137 present in the animal. Laboratory analyses verify field measurements and dose calculations estimate the dose to the hypothetical maximally exposed individual among the hunters. In 1995 this hypothetical hunter harvested three animals during the hunts. The estimated dose to this hunter was based on the cesium-137 measurements of the deer and hog muscle taken from these animals and the conservative assumption that the hunter consumed all edible portions of these animals [156 pounds (70.8 kilograms) of meat]. The estimated dose was 30 millirem (Arnett, Mamatey, and Spitzer 1996), which represents 30 percent of the DOE annual limit of 100 millirem (DOE Order 5400.5).

Table 4-11. Population distribution in 1996 within 50-mile (80-kilometer) radius of Savannah River Site.[a]

	Miles[b]						
Direction	0-5	5-10	10-20	20-30	30-40	40-50	Total
N	0	28	5,765	10,853	5,492	13,235	35,373
NNE	0	6	1,430	2,238	4,819	15,572	24,065
NE	0	1	3,191	3,172	5,712	11,053	23,129
ENE	0	29	3,387	4,858	5,786	44,195	58,255
E	0	168	7,308	5,748	9,554	4,698	27,476
ESE	0	39	1,686	2,093	2,938	3,526	10,282
SE	0	28	592	7,055	7,248	9,297	24,220
SSE	0	43	423	833	1,469	2,752	5,520
S	0	1	603	1,442	7,861	3,615	13,522
SSW	0	2	972	2,175	4,533	3,191	10,873
SW	0	18	1,023	2,428	2,825	2,883	9,177
WSW	0	65	1,195	7,707	2,478	6,306	17,751
W	0	59	3,591	8,604	8,666	7,349	28,269
WNW	0	486	3,621	115,805	54,542	12,520	186,974
NW	0	293	6,393	95,284	28,808	3,279	134,057
NNW	0	393	19,535	29,437	7,235	6,589	63,179
Total	0	1,659	60,715	299,732	159,9[illegible]6	150,060	672,122

a. Source: Simpkins (1996b).
b. To convert miles to kilometers, multiply by 1.6093.

In 1995 DOE assumed that the hypothetical maximally exposed individual fisherman ate 42 pounds (19 kilograms) of fish per year. The estimated dose to the fisherman, based on consumption of fish taken only from the mouth of Steel Creek on SRS, was 1.20 millirem (Arnett, Mamatey, and Spitzer 1996), or 1.2 percent of the DOE annual limit.

Gamma radiation levels, including natural background, terrestrial, and cosmic radiation measured at 179 locations around the SRS boundary during 1995, yielded a maximum dose rate of 106 millirem per year (Arnett, Mamatey, and Spitzer 1996). This level is typical of normal background gamma levels in the general area (100 millirem per year measured in Girard, Georgia, in 1995). The maximum gamma radiation level measured on the Site (N-Area) was 275 millirem per year (Arnett, Mamatey, and Spitzer 1996).

DOE provides detailed summaries of releases to the air and water from the SRS in a series of annual environmental reports (e.g., Arnett, Mamatey, and Spitzer 1996). Each of these reports summarizes radiological and nonradiological monitoring and the results of analyses of environmental samples. These reports also summarize the results of the extensive groundwater monitoring at SRS, which uses more than 1,600 wells to detect and monitor both radioactive and nonradioactive contaminants in the groundwater and drinking water in and around process operations, burial grounds, and seepage basins.

Radiation Levels in C-, K-, L-, P-, and R-Areas

Table 4-12 lists gamma radiation levels measured in C-, K-, L-, P-, and R-Areas in 1994. These values can be compared to the average dose rate of 35 millirem per year measured at the SRS boundary. This difference is attributable to differences in geologic composition and to facility operations.

Analyses of soil samples from uncultivated areas measure the amount of particulate radioactivity deposited from the atmosphere. Table 4-13 lists maximum measurements of radionuclides in the soil in 1995 for C-, K-, L-, P-, and R-Areas, the SRS boundary, and background [100-mile (160-kilometer)] monitoring locations. Elevated concentrations of strontium-90 and plutonium-239 measured around F- and H-Areas reflect releases from these areas.

Radiation Levels and Metals in L-Lake

TC

To support this EIS, DOE conducted a 2-year, full-scale contaminant study to develop a complete and defensible list of contaminants in L-Lake. The sampling locations chosen were biased toward areas of suspect contamination such as the original stream channel. In the following discussion, L-Lake includes both the lake itself and the original creek bed beneath the lake. Under the Proposed Action, Steel Creek would reestablish itself as a flowing stream.

Table 4-12. External radiation levels (milliroentgen per year) at Savannah River Site facilities.[a,b]

Location	Average	Maximum
C-Area	78	80
K-Area	79	93
L-Area	80	87
P-Area	80	88
R-Area	79	84

a. Source: Arnett, Mamatey, and Spitzer (1996).
b. One milliroentgen is approximately 1 millirem.

Table 4-13. Maximum measurements of radionuclides in soil for 1995 [picocuries per gram; 0 to 3 inches (0 to 8 centimeters) depth].[a] TE

Location	Strontium-90	Cesium-137	Plutonium-238	Plutonium-239
C-Area	0.00343	0.974	0.0881	0.616
K-Area	0.00290	1.01	0.0286	0.0923
L-Area	0.00300	0.152	0.0533	0.166
P-Area	0.00152	0.110	0.00144	0.0036
R-Area	0.00083	(b)	(b)	(b)
Site boundary	0.00185	0.424	0.00190	0.0149
Background [100-mile (160-kilometer radius)]	0.00741	0.355	0.000578	0.00681

TC

a. Source: Arnett, Mamatey, and Spitzer (1996).
b. Activity is below the lower level of detection.

However, for the purpose of this risk assessment, it is assumed that the entire creek bed would become exposed. As a result, no credit is taken for the shielding that this water would provide. Appendix F provides a more comprehensive description of the sampling program. Table 4-14 provides an average of all samples that screened above EPA risk-based guidelines. This method provides a conservative approach toward risk determination.

DOE in 1995 collected sediment cores from shallow and deep water locations in L-Lake. The 0- to 1-foot (31-centimeter) segments of these samples were analyzed for radioactive and nonradioactive constituents and the results were validated (Koch, Martin, and Friday 1996). In 1996 DOE collected additional surface soil and sediment cores from the submerged portions of the L-Lake basin. These samples were also analyzed for radioactive and nonradioactive constituents and the results validated (Dunn, Gladden, and Martin 1996; Dunn, Koch, and Martin 1996). To further reduce the number of potential constituents of concern, the validated nonradiological constituents results were then screened using the EPA Region 3 screening criteria (Dunn and Martin 1997). Similarly, the validated radiological constituent results were screened with the Westinghouse Savannah River Company Risk Based Activity screening criteria (Dunn and Martin 1997). TC

Table 4-14 lists the average concentrations of radionuclides and metals meeting the screening criteria for the samples taken in 1995 and 1996. DOE used these data for input to the Multimedia Environmental Pollutant Assessment System (MEPAS) computer code (Droppo et al. 1995) for impact analysis by spatially averaging these values over the entire lakebed. These values were also used for evaluations presented in Appendixes A and B. TC

Figure 4-22 presents a cesium-137 isodose contour of L-Lake.

Water samples from L-Lake were analyzed to determine concentrations of radionuclides and metals. Table 4-15 lists the results of these analyses.

4.1.8.1.2 Occupational Health

The major goal of the SRS Health Protection Program is to keep the exposure of workers to radiation and radioactive material within safe limits and, within those limits, as low as reasonably achievable. An effective radiation protection program must minimize doses to individual workers and the collective dose to all workers in a given work group.

Table 4-14. Average concentration and inventory of radionuclides and metals in L-Lake sediments.[a]

Contaminant	Concentration	Inventory
Radionuclides	(pCi/g)	(curies)
Cesium-137	5.8	11.6
Cobalt-60	0.09	1.8×10^{-1}
Plutonium-239/240	3.0×10^{-2}	5.9×10^{-2}
Promethium-146	1.4×10^{-2}	2.7×10^{-2}
Uranium-233/234	0.77	1.54
Metals	(μg/kg)	(grams)
Antimony	6.9×10^{3}	1.4×10^{7}
Arsenic	1.8×10^{4}	3.5×10^{7}
Beryllium	2.3×10^{2}	4.6×10^{6}
Cadmium	1.0×10^{3}	2.0×10^{6}
Lead	1.4×10^{4}	2.9×10^{7}
Manganese	3.0×10^{2}	6.1×10^{5}
Thallium	1.9×10^{4}	3.9×10^{7}

a. Source: Dunn and Martin (1997).

TC

Sources of Radiation Exposure to Workers at SRS

Worker dose comes from exposure to external radiation or from internal exposure when radioactive material enters the body. In most SRS facilities, the predominant source of worker exposure is from external radiation. In the SRS facilities that process tritium, the predominant source of exposure is the internal dose from tritium that workers have inhaled or absorbed into internal body fluids. On rare occasions, other radionuclides can contribute to internal dose if workers have accidentally inhaled or ingested them.

External exposure comes primarily from gamma radiation emitted from radioactive material in storage containers or process systems (tanks and pipes). Neutron radiation, which few special radionuclides emit, also contributes to worker external radiation in a few facilities. Beta radiation, a form of external radiation, has a smaller impact than gamma and neutron radiation because it has lower penetrating energy and, therefore, produces a dose only to the skin rather than to internal organs. Alpha radiation from external sources is nonpenetrating and produces no external exposure.

Internal exposure occurs when radioactive material is inhaled, ingested, or absorbed through the skin. Once the radioactive material is inside the body, low-energy beta and nonpenetrating alpha radiation emitted by the radioactive material in proximity to organ tissue can produce a dose to that tissue. If this same radioactive material were outside the body, the low penetrating ability of the radiation would prevent it from reaching the critical organs. To determine health hazards, organ dose can be converted to effective dose equivalents. The mode of exposure (internal versus external) is irrelevant when comparing effective dose equivalents.

SRS Worker Dose

The purpose of the radiation protection program is to minimize doses from external and internal exposure; it must consider both individual and collective doses. DOE could reduce individual worker dose to very low levels by using many workers to perform extremely small portions of the work task. However, frequent changing of

Table 4-15. Average surface water concentrations of radionuclides and metals in L-Lake.[a]

Contaminant	Concentration
Radionuclides	(pCi/ml)
Tritium	10.0
Metals	(μg/ml)
Barium	1.1×10^{-2}
Manganese	2.5×10^{-2}
Magnesium	1.2
Vanadium	4.6×10^{-4}
Beryllium	3.9×10^{-4}

a. Sources: Simpkins (1996c); Paller (1996).

workers would be inefficient and would result in a higher total dose received by all workers than if DOE used fewer workers and each worker received a slightly higher dose.

Worker doses at the SRS have consistently been well below the DOE worker exposure limits. Administrative exposure guidelines are set at a fraction of the exposure limits to help ensure doses are as low as reasonably achievable. For example, the current DOE worker exposure limit is 5 rem per year, and the SRS administrative exposure guideline was 0.7 rem per year in 1996 (WSRC 1995d). Table 4-16 lists maximum and average individual doses and SRS collective doses from 1988 through 1995.

Worker Radiological Risk

To compare the alternatives, this EIS quantifies risks associated with very small chronic exposures. These calculated risks are reasonably conservative estimates of actual risks included in a range that could include zero. In addition, because of the large uncertainties that exist in the dose-effect relationship, the Health Physics Society recently recommended against quantifying risks due to radiation exposures comparable to those calculated in this EIS [i.e., doses (in addition to background) less than 5 rem in a year or less than 10 rem in a lifetime] (HPS 1996). These uncertainties are due, in part, to the fact that epidemiological studies have been unable to demonstrate that these adverse health effects have occurred in individuals exposed to small doses (less than 10 rem) over a period of many years (chronic exposures) and the fact that the extent to which cellular repair mechanisms reduce the likelihood of cancers is unknown. Therefore, the radiological risks reported in this EIS should be used only for relative comparisons between alternatives and should not be interpreted as absolute or actual risks.

In the United States, 23.4 percent of human deaths each year are caused by some form of cancer (CDC 1996). Any population of 5,000 people is likely to contract approximately 1,200 fatal cancers from nonoccupational causes during their lifetimes, depending on the age and sex distribution. Workers who are exposed to radiation have an additional risk of 0.0004 latent fatal cancer per person-rem of radiation exposure (DOE 1995c).

In 1995, 5,157 SRS workers received a measurable dose of radiation amounting to 256 person-rem (Table 4-16). Therefore, this group could experience as much as 0.1 (0.0004×256) additional cancer death due to their 1995 occupational radiation exposure. Continued operation of the SRS could result in as much as 0.1 additional cancer death each year of operation, assuming future annual worker exposure continues at the 1995 level. In other words, for each 10 years of operation, there could be one additional death from cancer among the work force that receives a measurable dose at the 1995 level.

Table 4-16. Savannah River Site annual individual and collective radiation doses, 1988-1995.[a]

Year	Individual dose (rem) Maximum	Individual dose (rem) Average[b]	SRS collective dose (person-rem)
1988	2.040	0.070	864
1989	1.645	0.056	754
1990	1.470	0.056	661
1991	1.025	0.038	392
1992	1.360	0.049	316
1993	0.878	0.051	263
1994	0.957	0.024	314
1995	1.341	0.019	256

a. Adapted from: DOE (1995c), WSRC (1994b), Kvartek (1995, 1996).
b. The average dose is calculated only for workers who received a measurable dose during the year.

4.1.8.2 Environmental Impacts

This section discusses radiological and nonradiological exposures from L-Lake due to normal operations under the alternatives and subsequent impacts to the public and workers. This analysis shows that the health effects (specifically latent cancer fatalities and hazard indexes) associated with the alternatives would be small, and would be small in relation to those normally expected in the worker and regional area population groups from other causes.

The principal potential human health effect from exposure to low levels of radiation is cancer. Human health effects from exposure to chemicals can be toxic (e.g., nervous system disorders) or cancer. This analysis expresses radiological carcinogenic effects as the number of fatal cancers for populations and the maximum probability of death of a maximally exposed individual.

In addition to latent cancer fatalities, other health effects could result from environmental and occupational exposures to radiation. These effects include nonfatal cancers among the exposed population and genetic effects in subsequent generations. To enable comparisons with fatal cancer risk, the International Commission of Radiological Protection (ICRP 1991) suggested the use of detriment weighting factors that consider the curability rate of nonfatal cancers and the reduced quality of life associated with nonfatal cancer and heredity effects. The commission recommended probability coefficients (risk factors) for the general public of 0.0001 per person-rem for nonfatal cancers and 0.00013 per person-rem for hereditary effects. Both of these values are approximately a factor of 4 lower than the risk factors for fatal cancer. Therefore, this EIS presents estimated effects of radiation only in terms of latent cancer fatalities, because that is the major health effect from exposure to radiation.

For nonradiological carcinogenic health effects, risks are estimated as the incremental probability of an individual developing cancer (either fatal or nonfatal) over a lifetime as a result of exposure to the potential carcinogen. The overall potential for cancer posed by exposure to multiple chemicals is calculated by summing the chemical-specific cancer risks to determine a total individual lifetime cancer risk.

The potential for nonradiological noncarcinogenic health effects is evaluated by comparing an exposure level over a specified period with a reference dose derived for a similar exposure period. This ratio of exposure to toxicity is called a hazard quotient (EPA 1989). The noncancer hazard quotient assumes that there is a level of exposure below which even sensitive populations would be unlikely to experience adverse health effects. If the exposure level exceeded this threshold, there could be concern for potential noncancer effects.

To assess the overall potential for noncarcinogenic effects posed by more than one chemical, a hazard index approach is used (EPA 1989). This approach assumes that simultaneous subthreshold exposures to several chemicals could result in an adverse health effect. It also assumes that the magnitude of the adverse effect will be proportional to the sum of the ratios of the subthreshold exposures to acceptable exposures. The hazard index, therefore, is described as the sum of the hazard quotients. If the hazard index exceeds 1, there could be concern for potential health effects.

DOE used the MEPAS computer code (Droppo et al. 1995), a multipathway risk model developed by Pacific Northwest Laboratory, to assess the impacts of the No-Action, Shut Down and Deactivate, and Shut Down and Maintain Alternatives. The MEPAS code transports contaminants from a contaminated area to potential human receptors through various transport pathways (groundwater, surface water, soils, food, etc.). Human receptors receive both chemical and radiation doses through exposure or intake routes (ingestion, dermal contact, inhalation, etc.) and number of exposure pathways (drinking water, leafy vegetables, meat, etc.). MEPAS reports impacts for radiological exposures in terms of dose (rem) and cancer risk. For chemical exposures, it can report impacts as cancer risks or hazard index.

Because future use scenarios for the SRS include the use of Site lands for recreational activities (DOE 1996b), health impacts that could result from recreational use by members of the public are analyzed in this EIS. In addition, DOE has specified that future use scenarios of SRS land should include a full range of worker activities (PRC 1996). Therefore, this EIS includes potential impacts associated with these future and current land use worker scenarios. The following sections provide details of these scenarios.

Figures 4-23 and 4-24 show the pathways evaluated in this EIS for members of the public and workers, respectively. This EIS reports only impacts that would result from alternative actions that represent changes (incremental impacts) in relation to impacts from routine (baseline impacts) operation of the SRS (baseline impacts as presented in Section 4.1.8.1). However, the EIS estimates impacts that exist in the baseline case and are likely to change due to alternative activities, to enable the calculation of incremental changes for each alternative. Most of these impacts would be so small they could not be measured accurately and, therefore, must be calculated. Examples of these small impacts would include risks associated with exposure to volatilized tritium through inhalation and to mercury through dermal absorption resulting from contact with contaminated sediments.

4.1.8.2.1 No Action

The No-Action Alternative assumes L-Lake would remain at full pool [190 feet (58 meters) above mean sea level] and contaminated sediments would remain saturated and, therefore, would not become resuspended and available for transport to another location or inhalation. However, this analysis assumes that tritium would volatilize from the surface of the lake and become available for inhalation and absorption under current and future land use scenarios by members of the public and involved and uninvolved workers. Workers could also be exposed to contaminants in the surface water.

Public Health Impacts

The current land use scenario assumes that volatilized airborne tritium based on a 42-inch (1-meter)-per-year evaporation rate (del Carmen and Paller 1993a) would be transported off the SRS and become available for inhalation and ingestion by the offsite population living within

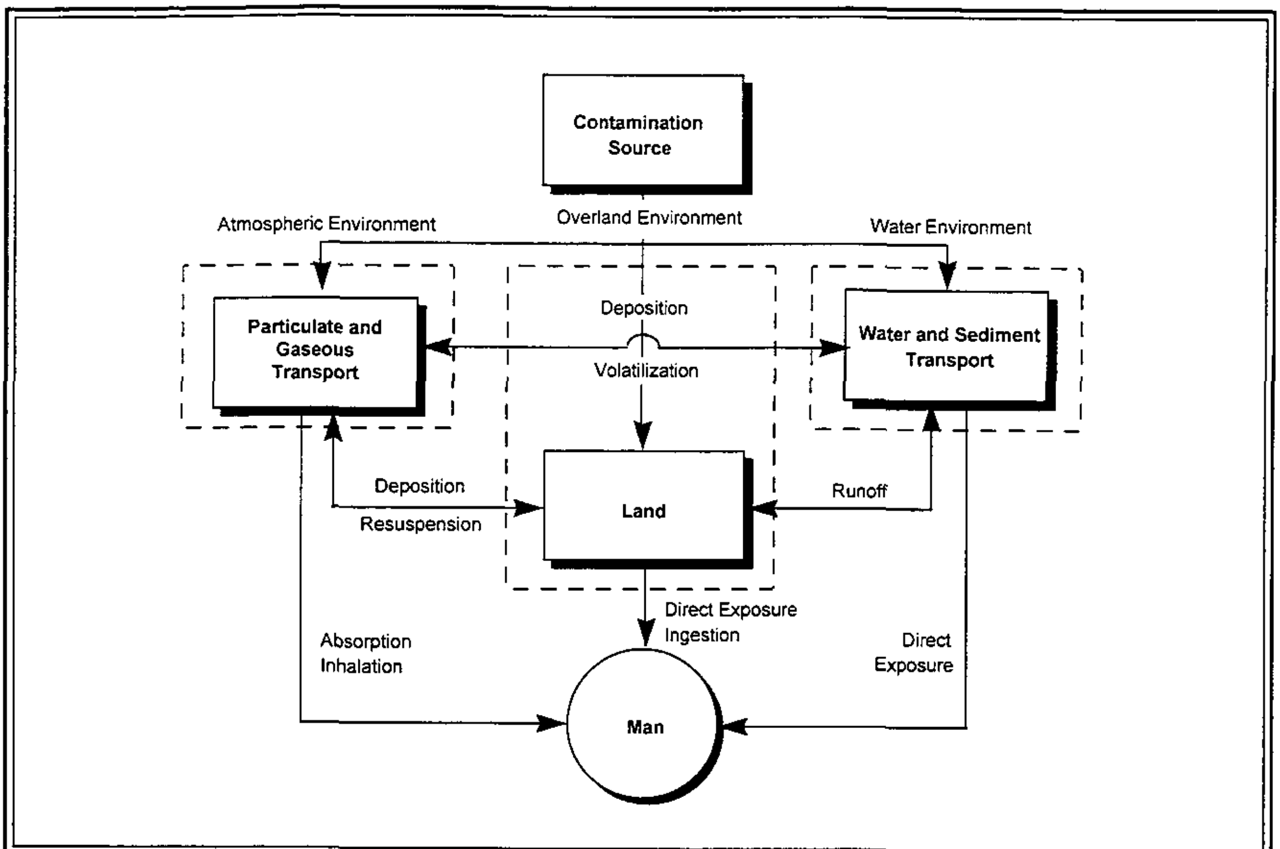

Figure 4-24. Worker exposure pathways.

50 miles (80 kilometers) of the Site. In addition, the future use scenario evaluates inhalation and absorption pathways resulting from recreational use of L-Lake (Figure 4-23) for other TE| constituents of concern listed in Table 4-15.

Radiological Impacts

Estimates of health effects associated with the No-Action Alternative on the public require the calculation of radiological doses to individuals and population groups. Estimates of latent cancer fatalities are calculated using the conversion factor of 0.0005 latent cancer fatality per rem for the general population (DOE 1995c). This factor is slightly higher than that for workers because infants and children are part of the general population.

Effects are estimated for the population group consisting of the 672,122 people living within 50 miles (80 kilometers) of SRS (Simpkins 1996b) and for the maximally exposed individual within this group. For this assessment, DOE assumed that the population would remain constant over the 70-year period of analysis. This assumption is justified because (1) current estimates indicate that the population will increase by less than 15 percent during this period (DOE 1995c), (2) there are uncertainties in the determination of year-to-year population distributions, and (3) although the absolute impacts would increase proportionately with population growth, the relative impact comparison between alternatives would not be affected.

The MEPAS code converts airborne radiological releases to doses. This code calculates the dose to a hypothetical maximally exposed individual at the SRS boundary (located in the southern compass sector for releases from L-Lake) and the collect ve dose to the population within a 50-mile (80-kilometer) radius. The current land use scenario under the No-

Action Alternative evaluates only the tritium volatilization and atmospheric pathways. The future use scenario, in addition to atmospheric pathways, includes pathways resulting from recreational use of L-Lake (Figure 4-23), which includes incidental ingestion of shoreline sediments and surface water, dermal contact with shoreline sediment and surface water, external direct exposure from shoreline sediments and surface water, and consumption of fish taken from the lake.

Table 4-17 lists the calculated atmospheric doses. *For the current land use scenario, the* annual doses (0.00015 millirem to the offsite maximally exposed individual and 0.0014 person-rem to the offsite population) would be small fractions of the dose from total SRS airborne releases in 1995 [0.06 millirem to the offsite maximally exposed individual and 3.5 person-rem to the population within 50 miles (80 kilometers) of SRS (Arnett, Mamatey, and Spitzer 1996)]. These doses from 1995 operations were well within the EPA requirements (40 CFR 161; DOE Order 5400.5), which restrict the annual dose limit to the offsite maximally exposed individual of 10 millirem from all airborne releases.

Using the fatal-cancer-per-rem dose factor provided above, DOE calculated the probability of the maximally exposed individual developing a fatal cancer and the numbers of fatal cancers that could occur in the regional population for the current land use scenario under the No-Action Alternative (Table 4-17). The probability of the maximally exposed individual dying of cancer as a result of 70 years of exposure to radiation under the No-Action Alternative is 1.3×10^{-9} or slightly more than 1 in a billion. Radiological doses and resulting health effects (number of fatal cancers) that could occur in the regional population of 672,122 people for this same exposure period would be 1.2×10^{-5}.

About 23.4 percent of deaths in the U.S. population are attributable to cancer from all causes; accordingly, the probability of an individual dying of cancer is 0.234, or approximately 1 in 4. In a population of 672,122 people [the number of people living within 50 miles (80 kilometers) of SRS], the number of people likely to die of cancer would be 157,000. Similarly, the annual risk of fatal cancer in the general population can be estimated (assuming a 70-year life expectancy) to be 3.3×10^{-3} per year. Thus, the incidence of radiation-induced fatal cancers associated with the No-Action Alternative (see Table 4-17) would be much smaller than the incidence of cancers from all causes. TC

For the future land use scenario, the calculated annual dose and resulting cancer risk (0.38 millirem to the maximally exposed individual and a 1.9×10^{-7} risk of latent fatal cancer) would be higher than for the current land use scenario because members of the public would be able to come into direct contact with the contaminated surface water of L-Lake. *However, this risk would be a small fraction of* the natural incidence of cancer from all causes.

Nonradiological Impacts

Table 4-18 lists the hazard index and cancer risk associated with the No-Action Alternative for members of the public. For the current land use scenario, hazard indexes are not calculated because the analysis assumes no releases of nonradiological constituents from L-Lake. However, the hazard index and cancer risk are calculated for the future land use scenario, which assumes that members of the public would use L-Lake for recreational activities. Under this scenario, exposure pathways would include incidental ingestion of shoreline sediments and surface water, dermal contact with shoreline sediment and surface water, and consumption of fish taken from the lake. TE

As listed in Table 4-18, the calculated hazard index (6.2×10^{-2}) for the maximally exposed individual under the future land use scenario would be less than one. TE

Table 4-18. Nonradiological hazard index associated with the No-Action Alternative for members of the public.[a]

Receptor	Annual (lifetime)[b] latent cancer risk[c]	Hazard index
Offsite maximally exposed individual (Future use)[d]	3.1×10^{-7} (2.1×10^{-5})	6.2×10^{-2}

a. See Table C-3 in Appendix C.
b. Based on 70 years of exposure.
c. Resulting from exposure to beryllium in surface water.
d. Assumes future recreational use of L-Lake.

The lifetime risk of fatal cancer due to exposure to beryllium in the surface water of L-Lake is 2.1×10^{-5}. This is a small fraction of the normal incidence of fatal cancers (0.234) in the exposed population from all causes.

Occupational Health

Radiological Impacts

Estimated doses and the resulting impacts to involved workers are based on a review of exposures resulting from the No-Action Alternative. For the current land use scenario, the involved worker is assumed to be a researcher who spends 6 hours per week (Hamm 1996), 15 weeks per year in the vicinity of L-Lake. The current worker is assumed to have a 5-year career exposure period (Hamm 1996). During the time spent around L-Lake, the worker's arms and hands are in contact with shoreline sediments. Other exposure pathways evaluated include incidental ingestion of shoreline sediments and direct radiation exposure to sediments (Figure 4-24). To evaluate shoreline sediment exposure pathways, the MEPAS computer code calculated the concentration of radionuclides in L-Lake shoreline sediments based on ambient water concentrations of the radionuclides (Table 4-15). This method will estimate the incremental impacts (above baseline) resulting from exposure to shoreline sediments that are exposed while L-Lake is maintained at full pool under the No-Action Alternative. The future land use scenario assumes the same exposure pathways as the current land use scenario, except the worker would spend 2,000 hours per year (8 hours per day for 250 days a year) in the vicinity of L-Lake. The future worker is assumed to have a 25-year career exposure period.

An evaluation (Appendix C) determined the hypothetical maximally exposed uninvolved worker is in L-Area [approximately 2 miles (3.2 kilometers) from the release point (center of L-Lake)]. This individual is assumed to be exposed for 40 hours a week. Population doses were calculated for the uninvolved workers in this area based on a population of 251 workers (Simpkins 1996c). Doses were estimated for the inhalation, ground contamination, and plume immersion exposure pathways. Table 4-19 lists incremental worker doses (the increase in dose due to activities under the No-Action Alternative). DOE regulations (10 CFR 835) require that annual doses to individual workers not exceed 5 rem per year. DOE requires that exposure to the maximally exposed involved worker at the SRS does not exceed 0.7 rem per year administratively (WSRC 1995d).

From these radiological doses, estimates of latent cancer fatalities were calculated using the conversion factor for workers of 0.0004 latent cancer fatality per rem (ICRP 1991). Based on this factor, the probability that the average involved worker would develop a fatal cancer sometime during his lifetime as the result of a single year's exposure to radiation under the No-Action Alternative and current land use scenario would be 2.0×10^{-11}. For the total involved workforce, the collective radiation dose

Table 4-19. Worker radiological doses associated with the No-Action Alternative and resulting health effects.[a]

Receptor(s)	Individual: Dose (rem)	Individual: Probability of fatal cancer	All workers: Dose (person-rem)	All workers: Number of fatal cancers
Involved worker[b] (current use)				
Annual[c]	5.0×10^{-8}	2.0×10^{-11}	3.5×10^{-6}[d]	1.4×10^{-9}
Lifetime[e]	2.2×10^{-7}	8.7×10^{-11}	1.5×10^{-5}	6.1×10^{-9}
Involved worker (future use)[b]				
Annual[c]	1.1×10^{-6}	4.4×10^{-10}	7.7×10^{-5}	3.1×10^{-8}
Lifetime[e]	1.5×10^{-5}	5.9×10^{-9}	1.0×10^{-3}	4.1×10^{-7}
Uninvolved worker[f]				
Annual[c]	2.0×10^{-8}	7.8×10^{-12}	4.9×10^{-6}	2.0×10^{-9}
Lifetime[e]	2.6×10^{-7}	1.1×10^{-10}	6.6×10^{-5}	2.6×10^{-8}

a. See Tables C-4, C-5, and C-6 in Appendix C.
b. The estimated number of involved workers would be 70.
c. Annual individual worker doses can be compared to the regulatory dose limit of 5 rem (10 CFR 835) and the SRS administrative exposure guideline of 0.7 rem. Operational procedures ensure that the dose to the maximally exposed worker will remain as far below the regulatory dose limit as is reasonably achievable. Based on a total of 13,651 monitored workers (Kvartek 1996), the 1995 average dose for Site workers who received a measurable dose was 0.019 rem (See Table 4-16).
d. Total for all involved workers; 1995 SRS total for all workers was 256 person-rem (see Table 4-16).
e. Based on 5 years of exposure for current workers and 25 years of exposure for future and uninvolved workers. Doses are corrected for radioactive decay.
f. L-Area. Total uninvolved workers estimated to be 251 [Source: Simpkins (1996c)].

could produce up to 1.4×10^{-9} additional fatal cancer as the result of a single year's exposure; over a 5-year career, the involved workers could have 6.1×10^{-9} additional fatal cancer as a result of exposure.

Under the future land use scenario, the probability that the average involved worker would develop a fatal cancer sometime during his lifetime as the result of a single year's exposure to radiation under the No-Action Alternative would be 4.4×10^{-10}. For the total involved workforce, the collective radiation dose could produce up to 3.1×10^{-8} additional fatal cancer as the result of a single year's exposure; over a 25-year career, the involved workers could have 4.1×10^{-7} additional fatal cancer as a result of exposure.

The annual probability of an individual uninvolved worker developing a fatal cancer as a result of the estimated exposure would be 7.8×10^{-12}. For the total uninvolved workforce, the collective radiation dose could produce up to an additional 2.0×10^{-9} fatal cancer as the result of a single year's exposure; over a 25-year career, the uninvolved worker could have an additional 1.1×10^{-10} risk of developing a fatal cancer and 2.6×10^{-8} additional fatal cancer in the workforce.

The calculated numbers of fatal cancers due to worker exposure to radiation can be compared to the number of fatal cancers that would normally be likely among the workers during their lifetimes. Population statistics indicate that, of the U.S. population that died in 1994, 23.4 percent died of cancer (CDC 1996). If this percentage of deaths from cancer remains constant, 23.4 percent of the U.S. population will develop a fatal cancer during their lifetime. Therefore, in the group of 70 involved workers, about 16 normally would be likely to die of cancer.

The probability of developing a radiation-induced fatal cancer associated with the No-Action Alternative would be much less than the probability of developing a fatal cancer from other causes. The impacts from the alternatives discussed in this EIS would be a small fraction of the incidence of fatal cancer from all causes.

Nonradiological Impacts

DOE calculated nonradiological health impacts (hazard index and cancer risk) for the current and future land use involved worker. The exposure pathways and exposure times would be the same as those discussed previously. The hazard index for the uninvolved worker was not calculated because under the No-Action Alternative, chemical constituents are not assumed to be released to the atmosphere; therefore atmospheric exposure pathways would not exist for this individual. Table 4-20 lists the results; the calculated hazard index for the maximally exposed involved worker under the current and future land use scenarios would be a small fraction of 1. Therefore, these individuals would be not be likely to experience adverse health effects.

4.1.8.2.2 Shut Down and Deactivate

This alternative assumes that L-Lake would recede to the original Steel Creek stream channel, thereby exposing contaminated sediment. These sediments would dry, become resuspended in the atmosphere, and be available for inhalation by onsite workers and the offsite population within 50 miles (80 kilometers) of SRS. In addition, soil erosion would be likely, which would cause sediments to become entrained in storm water and appear in Steel Creek and the Savannah River. However, the recession of the lake would remove the tritium volatilization pathway discussed above from consideration. The following sections describe the specific pathways evaluated for each receptor.

Public Health

Radiological Impacts

To estimate the health effects associated with the Shut Down and Deactivate Alternative on the public, radiological doses were calculated only to the maximally exposed individual and population groups for the current land-use scenario only. Because L-Lake would recede to the original stream channel, the future recreational land use scenario would not exist.

Table 4-20. Worker nonradiological hazard indexes and cancer risks associated with the No-Action Alternative.[a]

Receptor(s)	Annual (lifetime)[b] latent cancer risk	Hazard index
Involved worker (current use)	9.1×10^{-9} (4.5×10^{-8})	2.1×10^{-4}
Involved worker (future use)	1.3×10^{-8} (3.1×10^{-7})	4.8×10^{-5}
Uninvolved worker[c]	NC[d]	NC

a. See Tables C-7 and C-8 in Appendix C.
b. Based on 5 years of exposure for current worker and 25 years of exposure for future and uninvolved workers.
c. L-Area.
d. NC = not calculated; nonradiological constituents are not released under the No-Action Alternative.

For the Shut Down and Deactivate Alternative, in addition to the 672,122 people living within 50 miles (80 kilometers) of SRS who would be exposed through the atmospheric pathways, doses from aqueous releases were calculated for the 65,000 people (Arnett, Mamatey, and Spitzer 1996) who use the Savannah River for drinking water (Port Wentworth, Georgia, and Beaufort and Jasper Counties, South Carolina) and who would be exposed to releases to the River. As discussed previously for atmospheric releases from L-Lake, the maximally exposed individual would be at the Site boundary in the southernmost compass sector. However, for aqueous releases, this individual is assumed to drink untreated water from the River at a location just south of the SRS boundary and, conservatively, to be the same maximally exposed individual from atmospheric releases.

As with atmospheric pathways, the MEPAS code calculated doses and impacts from waterborne releases. This code calculated the dose to a hypothetical maximally exposed individual along the Savannah River just downstream of SRS, and to the population using the River from SRS to the Atlantic Ocean. Fish ingestion, water ingestion, shoreline sediment ingestion, and recreational exposure pathways were included in the calculation for the maximally exposed individual. Downstream population doses were calculated from the ingestion of water from the Savannah River.

As for the atmospheric assessments, the population was assumed to remain constant over the 70-year period of analysis.

Table 4-21 lists calculated doses resulting from releases to air and water under the Shut Down and Deactivate Alternative. The annual doses (4.2×10^{-4} millirem to the offsite maximally exposed individual and 4.6×10^{-4} person-rem to the offsite population) would be small fractions of the doses from total SRS releases to water in 1995 [0.20 millirem to the maximally exposed member of the public and 5.1 person-rem to the population (Arnett, Mamatey, and Spitzer 1996)].

Table 4-21 also lists the annual and lifetime probability of the maximally exposed individual developing a fatal cancer and the numbers of fatal cancers that could occur in the regional population under the Shut Down and Deactivate Alternative. The probability of the maximally exposed individual dying of cancer as a result of 70 years of exposure to radiation is 9.7×10^{-9}; the number of additional fatal cancers in the regional population for this same exposure period would be 1.0×10^{-5}.

Nonradiological Impacts

Table 4-22 lists the hazard indexes associated with the Shut Down and Deactivate Alternative. Hazard quotients were calculated for atmospheric and aqueous exposure pathways for the current land use scenario.

As listed in Table 4-22, the calculated total hazard index for the maximally exposed individual is a small fraction of one. Therefore, this individual would not be likely to experience adverse health effects. In addition, the lifetime cancer risk to the maximally exposed individual would be 5.6×10^{-7}.

Occupational Health

Radiological Impacts

DOE estimated doses to involved and uninvolved workers for the Shut Down and Deactivate Alternative using the exposure assumptions discussed above with the additional pathway resulting from inhalation of resuspended, dried sediments. The doses and resulting impacts (although still very small) have increased over the No-Action Alternative due to the exposed sediments.

The incremental worker doses (the increase in dose due to activities under the No-Action Alternative) are listed in Table 4-23. These doses

Table 4-22. Nonradiological hazard index and cancer risks associated with the Shut Down and Deactivate Alternative for members of the public.[a]

	No-Action Alternative		Shut Down and Deactivate Alternative			
Receptor(s)	Hazard index[b]	Annual (lifetime)[c] latent cancer risk[d]	Atmospheric release hazard index	Aqueous release hazard index	Total hazard index	Annual (lifetime)[c] latent cancer risk[e]
TC Offsite maximally exposed individual	6.2×10^{-2}	3.1×10^{-7} (2.1×10^{-5})	6.9×10^{-3}	2.1×10^{-1}	2.2×10^{-1}	8.0×10^{-9} (5.6×10^{-7})

a. Supplemental information is provided in Tables C-13 and C-14 in Appendix C.
b. Future land use scenario.
c. Assumes 70 years of exposure.
d. Resulting from exposure to beryllium in surface water.
e. Resulting from exposure to cadmium, arsenic, and beryllium in contaminated sediments.

represent a small fraction of the DOE limit (10 CFR 835) that require that annual doses to individual workers not exceed 5 rem per year as well as a small fraction of the SRS administrative limit of 0.7 rem per year (WSRC 1995d).

TC The probability that the average involved worker would develop a fatal cancer sometime during his lifetime as the result of a single year's exposure to radiation under the Shut Down and Deactivate Alternative and current land use scenario would be 9.7×10^{-8}. For the total involved workforce, the collective radiation dose could produce up to 6.8×10^{-6} additional fatal cancer as the result of a single year's exposure; over the worker's 5-year career, the involved worker population could have 3.2×10^{-5} additional fatal cancer as a result of exposure.

TC Under the future land use scenario, the probability that the average involved worker would develop a fatal cancer sometime during his lifetime as the result of a single year's exposure to radiation would be 1.6×10^{-5}. For the total involved workforce, the collective radiation dose could produce up to 1.1×10^{-3} additional fatal cancer as the result of a single year's exposure; over the worker's 25-year career, the involved worker population could have 2.1×10^{-2} additional fatal cancer as a result of exposure.

TC The probability of any individual uninvolved worker developing a fatal cancer as a result of a single year of exposure would be 5.7×10^{-10}. For the total uninvolved workforce, the collective radiation dose could produce up to an additional 1.4×10^{-7} fatal cancer as the result of a single year's exposure; over the worker's TC 25-year career, the uninvolved worker population could have an additional 3.5×10^{-6} additional fatal cancers.

Nonradiological Health

Nonradiological health impacts (hazard index) were calculated for the current and future land use scenarios for the involved worker. The exposure pathways and exposure times would be the same as those discussed previously. Table 4-24 lists the results. As listed, the calculated hazard indexes for the maximally exposed involved worker under the current and future land use scenarios (1.1×10^{-2} and 2.1×10^{-1}, respectively) would be a small fraction of one. Therefore, these individuals would be not be likely to experience adverse health effects.

Table 4-24. Worker nonradiological hazard indexes and cancer risks associated with the Shut Down and Deactivate Alternative.[a]

	No-Action Alternative		Shutdown and Deactivate Alternative	
Receptor(s)	Annual (lifetime)[b] latent cancer risk[c]	Hazard index	Annual (lifetime)[b] latent cancer risk[d]	Hazard index
Involved worker (current use)	9.1×10^{-9} (4.5×10^{-8})	2.1×10^{-4}	6.6×10^{-8} (3.3×10^{-7})	1.1×10^{-2}
Involved worker (future use)	1.3×10^{-8} (3.1×10^{-7})	4.8×10^{-5}	1.2×10^{-6} (2.9×10^{-5})	2.1×10^{-1}
Uninvolved worker[e]	NC[f]	NC	1.4×10^{-9} (3.6×10^{-8})	1.1×10^{-4}

a. See Tables C-20 and C-21 in Appendix C.
b. Based on 5 years of exposure to the current worker and 25 years of exposure for future and uninvolved workers.
c. Due to exposure to beryllium in surface water.
d. Due to exposure to airborne cadmium, arsenic, and beryllium.
e. L-Area.
f. NC = not calculated; nonradiological constituents are not released under the No-Action Alternative.

For the uninvolved worker assumed to be in L-Area, the calculated hazard index of 1.1×10^{-4} would be a small fraction of 1 and, therefore, this individual would be not be likely to experience adverse health effects. The probability of the uninvolved worker developing a fatal cancer due to a lifetime of exposure would be 3.6×10^{-8}.

4.1.8.2.3 Shut Down and Maintain

For the Shut Down and Maintain Alternative, the water level in L-Lake would be likely to recede to the original Steel Creek stream channel in a similar manner as that described for the Shut Down and Deactivate Alternative. Therefore, the impacts to workers and member of the public under Shut Down and Maintain would be the same as the impacts under Shut Down and Deactivate.